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The Mantevo Project
Mini-applications: Vehicles for Co-Design

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Introduction

Application performance is determined by a combination of many choices: architecture characteristics and capabilities, runtime environment, programming model and mechanisms, languages, compilers, algorithm, implementation, and more. In this complicated environment, we find that the use of mini-applications – small self-contained proxies for full applications – is an excellent approach for rapidly exploring the parameter space of all these choices. Furthermore, use of mini-applications enriches the interaction between application, library and computer system developers by providing explicit functioning software and concrete performance results that lead to detailed, focused discussions of design trade-offs, algorithm choices and runtime performance issues. In this poster we describe a collection of mini-applications and demonstrate how we use them to analyze and improve application performance on new and future computer platforms.

Mantevo miniapps have been used to explore programming models (including TBB, pthreads, qthreads, OpenMP, CUDA, and OpenCL), algorithm options, architectures (including Intel MIC, Nvidia GPU accelerated CPU clusters, and AMD Fusion), energy consumption, checkpoint/restart and data compression, in-situ visualization, memory hierarchies, node interconnects, and data partitioning strategies. We present some of those experiments in this poster.

Mantevo miniapps

The Mantevo project (*mantevo.org)* began as a laboratory funded research project (LDRD) at Sandia National Laboratories in 2008. The current set of Mantevo miniapps includes

CloverLeaf	Compressible Euler eqns, explicit 2nd order accurate
CoMD	Molecular dynamics (SPaSM)
HPCCG	Unstructured implicit finite element
miniFE	Implicit finite element solver
miniGhost	FDM/FVM explicit (halo exchange focus)
miniMD	Molecular dynamics (Lennard-Jones)
miniXyce	SPICE-style circuit simulator
mini"Aero"	Aeodynamics
miniAMR	Adaptive mesh refinement of an Eulerian mesh
miniExDyn-FE	Explicit Dynamics (Kokkos-based)
miniITC-FE	Implicit Thermal Conduction (Kokkos-based)
mini"Wave"	Arbitrary Lagrange Eulerian re-mapping.
phdMesh	Explicit FEM: contact detection

Initial Release Version 1.0

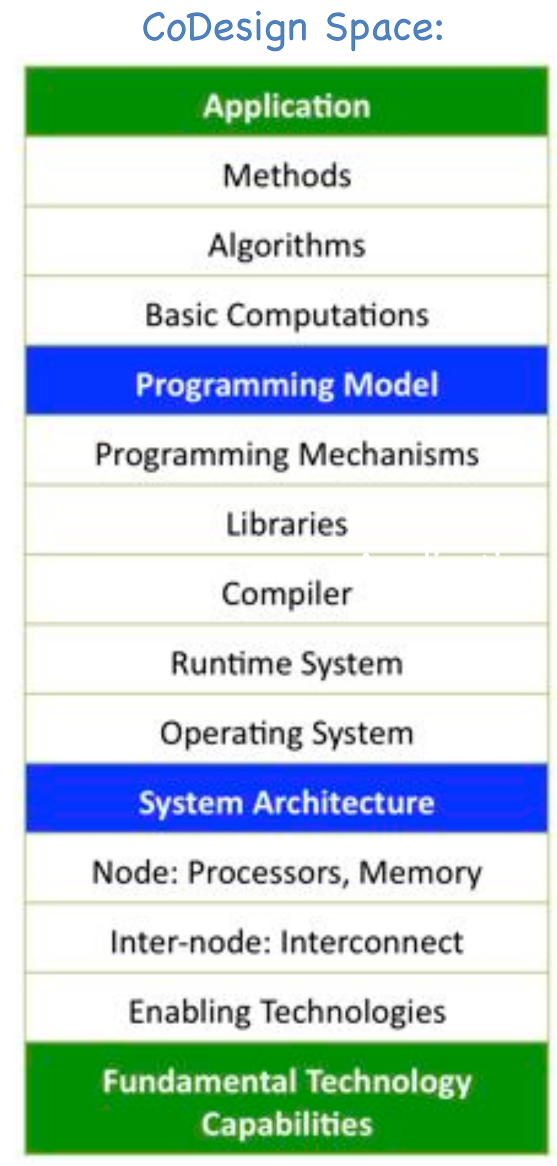
Characteristics of a miniapp

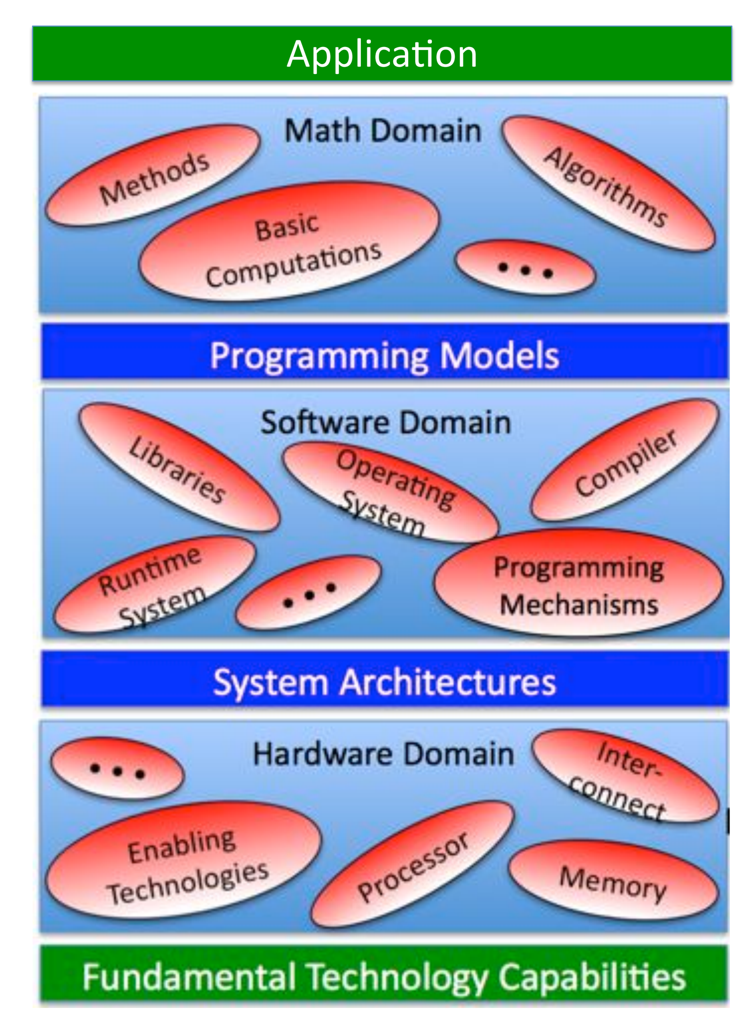
Miniapps are designed as tools, useful throughout the co-design space, from hardware registers to the application. *Unlike a benchmark*, the result of which is a value to be ranked, the output of a miniapp is information, which must be interpreted within some often subjective context. *Unlike a compact application*, which is designed to capture some sort of physics behavior, miniapps are designed to capture some key performance issue in the full application. *Unlike a skeleton application*, which is designed for only focusing on inter-process communication perhaps involving a "fake" computation, miniapps create a meaningful context in which to explore the key performance issue. Miniapps are developed and owned by application code teams. Miniapps are intended to by modified, and thus are limited to a few thousand lines of code, allowing for unconstrained modification. Once no longer useful for these purposes, a miniapp's life will end. *Miniapps are freely available* as open source software under an LGPL license.

CoDesign

CoDesign is a *model for cooperation* across the various components and disciplines that comprise a scientific or engineering application code. This approach requires iterative interaction across the boundaries throughout the space. Miniapps have been identified as a critical tool for codesign in the development of an Exascale computing capability by the Department of Energy's NNSA ASC campaign.

CoDesign Space:



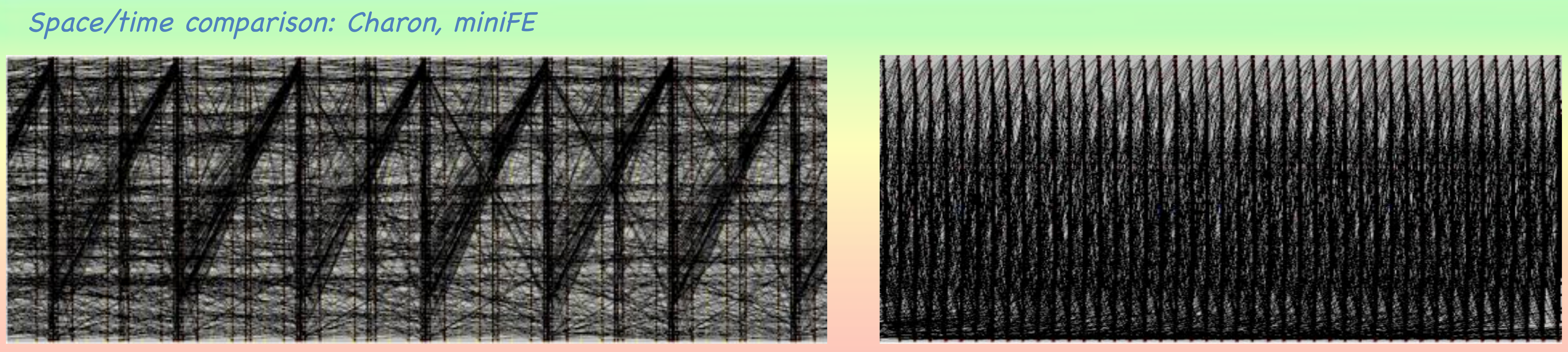


Can miniFE serve as a proxy for Charon?

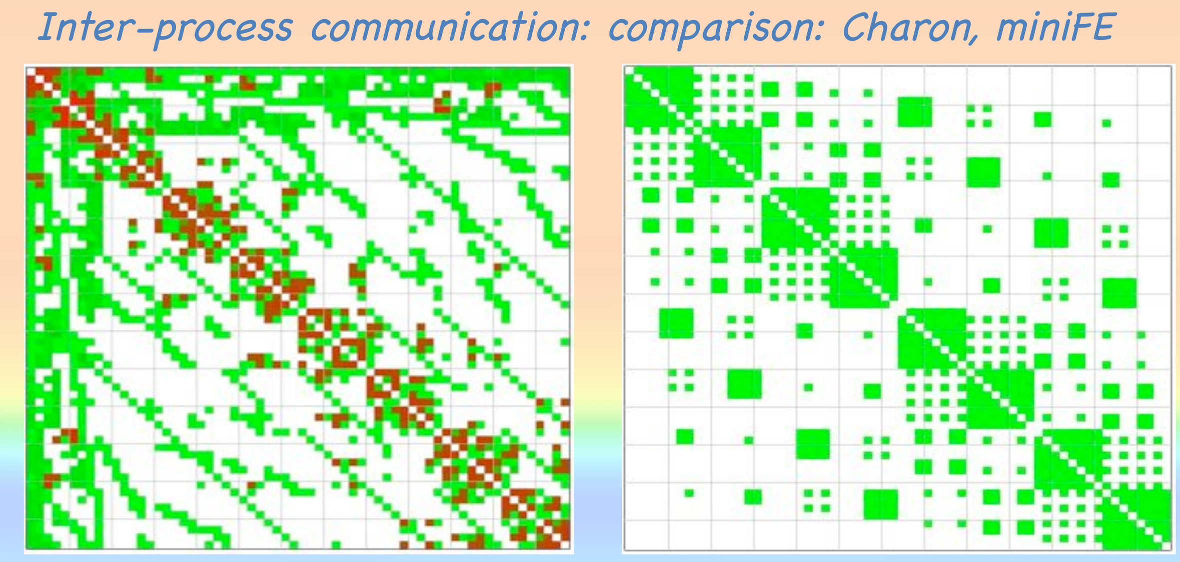
Charon is a *semiconductor device simulation code.* An implicit finite element method approach solves the steady-state drift-diffusion for a bipolar junction transistor (BJT). It employs a Newton-Krylov solver, based on GMRes with a multilevel, distributed memory algebraic preconditioner, both from the Trilinos project.

MiniFE (an extension of HPCCG) is a miniapp that *mimics the finite element generation, assembly and solution for an unstructured grid problem.* The physical domain is a 3D box with configurable dimensions and a structured discretization (which is treated as unstructured). The domain is decomposed using a recursive coordinate bisection (RCB) approach and the elements are simple hexahedra. The problem is linear and the resulting matrix is symmetric, so a standard conjugate gradient algorithm is used with a general sparse matrix data format and no preconditioning.

Space/time comparison: Charon, miniFE



Inter-process communication: comparison: Charon, miniFE



Perf	miniFE		Charon		
	CG	FE +BC	ML prec	TFQMR	Mat +RHS
L1 HR	99.8	99.9	99.8	99.2	99.7
L2 HR	95	67	79	81	98.3
L3 HR	13	48	37	17	98.4
%peak	4.4	12	0.7	3.2	1.2

Cache performance, Cray XE6 node: dual-socket 8-core Magny-Cours, 16 MPI ranks; gcc 4.5.2 –O2; PAPI perftool

Further reading
- "Improving Performance via Mini-applications", M.A. Heroux, D.W. Doerfler, P.S. Crozier, J. Willenbring, H.C. Edwards, A.Williams, M.Rajan and Keiter, Thornquist, and Numrich, Technical Report, SAND2009-5574, 2009.
- "Summary of Work for ASC L2 Milestone 4465: Characterize the Role of the Mini-Application in Predicting Key Performance Characteristics of Real Applications", R.F. Barrett (PI), P.S. Crozier, D.W. Doerfler (PM), S.D. Hammond, M.A. Heroux, H.K. Thornquist, T.G. Trucano, and C.T. Vaughan, Sandia Technical Report SAND 2012-4667, Sandia National Laboratories, 2012.
- "IESP Exascale Challenge: Co-Design of Architectures and Algorithms", A. Geist and S. Dosanjh, International Journal of High Performance Computing, 2009.

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